Modern Drought Monitoring Tool for Decision Support System

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INTRODUCTION

Drought is a natural disaster that influences many aspects of society. Since the demand for water is increasing along with the population in many parts of the world, water supply interruptions caused by drought can be expected to produce greater impacts. This is because the impacts of drought are determined not only by the frequency and intensity of meteorological drought but also by the number of people at risk and their degree of risk (Wilhite, 2000). For example, the increase in population in Africa and Asia increases drought vulnerability significantly. Thus, policies that promote the development and implementation of appropriate drought mitigation measures today will help to reduce the economic, social, and environmental impacts associated with future droughts and the need for government intervention.

To monitor drought, different types of indicators (e.g., drought indices) have been used in many parts of the world. Because there is no single definition for drought, determining which indicators to use poses more difficulties for planners. Decision makers use different policies and strategies based on the historical records of their countries. For example, in Australia, when meteorological drought (annual rainfalls in the lowest 10% of recorded values) occurred over at least 10% of the continent, it coincided with damaging agricultural droughts resulting significant losses of crops and livestock (Heathcote, 2000).

Because of the varied and potentially catastrophic losses resulting from drought in many parts of the world, both governmental and non-governmental decision makers need better predictive and monitoring tools to assist them in dealing more effectively with drought. Better early warning and prediction is the foundation of a new drought management paradigm based on risk management. In South Africa, the Weather Bureau issues extended outlooks for short and long periods using numerical modeling and statistical methods (Vogel, Lang, & Monnik, 2000). In United States, recent advances in science and technology are enhancing drought monitoring capabilities and the availability of such information, which allows decision makers to make more knowledge-based decisions to lessen the impacts of drought.

In this article, we highlight the role of government in drought planning and mitigation, the potential of data mining techniques and their outputs (e.g., maps and tables) for improving informed decision making, and also present a newly developed drought monitoring tool, the Vegetation Drought Response Index (VegDRI) as an example over the central United States.

BACKGROUND

Recurrent droughts and their significant impacts on societies are increasingly forcing governments to play a more significant role in drought management in many parts of the world. Given the complexity of drought, where the impacts can accumulate gradually over time and vary widely across many sectors, a well-designed decision support system is critical to effectively manage drought mitigation and response efforts (Goddard, Harms, Reichenbach, Tadesse, & Waltman, 2003). The traditional mindset of government in the United States and elsewhere has been to react to drought (i.e., crisis management approach) through the provision of relief or emergency assistance to the affected areas or sectors. With this approach, drought only receives the attention of decision makers when it is at peak levels of intensity and spatial extent and when water management options are quite limited. This approach has been characterized as ineffective, poorly coordinated, and untimely (Riebsame, Changnon, & Karl, 1991; Wilhite, 2000; Wilhite & Wood, 1994). Not only is this approach extremely costly, relief provided through this process is often politically driven, programmatically misdirected, and poorly targeted. Relief often serves as a disincentive for the sustainable management of natural resources because it reinforces existing management practices, practices that may not be sustainable in the long term. This reactive approach is not good policy and must be replaced by an anticipatory, preventive approach that reduces risk through the adoption of appropriate mitigation programs and policies (e.g., risk management approach). Today, nations are increasingly pursuing a more proactive approach that emphasizes the principle of risk management and sustainable development (Wilhite, 2000).

Technological advances and better use of available drought monitoring tools improves our ability to more effectively manage water and other shared natural resources during periods of drought. These changes can facilitate the shift to risk management because they allow governments on the national, state, and local level to address some of the more serious deficiencies of the crisis management approach. For example, our ability to monitor and disseminate critical drought-related information has been enhanced by new technologies such as automated weather stations, satellites, computers, and improved communication techniques (e.g., the Internet).

Previous drought planning efforts have been hampered by a lack of adequate early warning systems and insufficient information flow within and between levels of government. However, an improved understanding of complex atmospheric-oceanic systems and the development of new computer models have improved drought forecast skills for some regions. If they become part of a comprehensive early warning system, these advancements and others can provide decision makers with better and timely information. One of the recently developed techniques relevant for such drought monitoring and prediction is data mining.

THE USE OF DATA MINING TECHNOLOGIES IN IDENTIFYING DROUGHT

Data mining is a technique that uses a variety of data analysis tools to discover meaningful patterns and relationships of physical variables in different data sets (Berry & Linoff, 2000; Han & Kamber, 2001; Two Crows, 1999). This technique is used in multidisciplinary fields, bringing together techniques from machine learning, pattern recognition, statistics, databases, and visualization to address the issue of information extraction from large databases (Cabena, Stadler, Verhees, & Zanasi, 1998). The method has been used for commercial applications to increase profits (Cabena et al., 1998; Groth, 1998). These techniques are being utilized more frequently to extract hidden relationships and information from large databases to allow managers to make knowledge-based decisions (Berry & Linoff, 2000).

Data mining can also provide mechanisms for resourceful and efficient data handling and extraction of information in drought research. This is extremely important because monitoring and prediction of drought relies heavily on the use of climatic, oceanic, satellite, and biophysical data. At present, extracting useful information from these data and producing drought monitoring tools hold many challenges. Data mining techniques such as association rules, decision trees, and neural networks can help in finding a relationship among meteorological, satellite, oceanic, and biophysical variables.

Recent studies have applied data mining techniques to understanding drought characteristics in the central United States (Harms, Deogun, & Tadesse, 2002; Tadesse, Wilhite, Harms, Hayes, & Goddard, 2004). Harms et al. (2002) developed data mining algorithms that identify the drought episodes separate from normal and wet conditions. The algorithms generate association rules defined as "if X then Y," where X is the rule antecedent and Y is its consequent. Tadesse et al. (2004) used this rule-based association technique with the global oceanic indices as antecedent episodes and drought as consequent episode to find the relationships between climatic and oceanic parameters within the state of Nebraska. This study indicates that there is a strong relationship between the global oceanic condition and drought occurrence in Nebraska. This information is important in helping to predict future drought occurrences. Studies in ecological research have also introduced data mining techniques and found that they are powerful tools to address complex ecological problems involving both numeric and categorical data (De'ath & Fabricius, 2000).

In another drought monitoring research study, Brown, Tadesse, Hayes, and Reed (2005) focused on simple